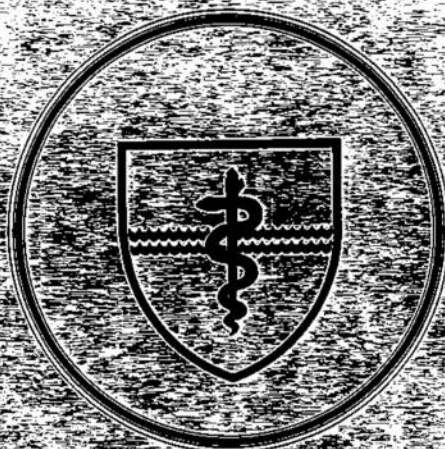


NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY SUBMARINE BASE, GROTON, CONN.



REPORT No. 1100
RIGID GAS PERMEABLE CONTACT LENSES
IN HYPERBARIC ENVIRONMENTS

by

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Naval Medical Research and Development Command
Research Work Unit MR00001.01-5104

Released by:

C. A. Harvey, CAPT, MC, USN

COMMANDING OFFICER

Naval Submarine Medical Research Laboratory

18 August 1987

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SUMMARY PAGE

PROBLEM

Navy divers who wear spectacles for the correction of defective visual acuity often dive without visual correction or use a prescription faceplate where practical. This creates the problem of storing their spectacles while diving and finding them again when they surface. Contact lenses could solve this problem. However, it is unknown what detrimental effects might occur to the corneal physiology while diving.

FINDINGS

Bubbles were found to form rapidly under the central optic zone area of rigid gas permeable contact lenses during decompression from depths as shallow as 37.5 feet. These bubbles mildly affected corneal physiology by inducing localized epithelial edema. The contact lens wearers were unaware of the bubbles.

APPLICATION

In a previous study, it has been shown that soft contact lenses can safely be worn while diving; however, this study revealed that there is increased involvement of the corneal epithelium when wearing rigid gas permeable contact lenses under pressure. Therefore, rigid lenses should be worn with caution while diving.

ADMINISTRATIVE INFORMATION

This research was conducted as part of the Naval Medical Research and Development Command Work Unit MR00001.01-5104 - "Effects of hyperbaric conditions on corneal physiology." It was submitted for review on 23 July 1987, approved for publication on 18 August 1987, and designated as NSMRL Report No. 1100.

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ABSTRACT

We studied the effects of decompression in a hyperbaric environment on individuals wearing hard, gas-permeable contact lenses. Twenty-four exposures with lenses made of three different materials were carried out in a hyperbaric chamber. The dry air dive profiles were: 150 feet for 30 minutes and 15 minutes, 75 feet for 15 minutes, and 37.5 feet for 15 minutes. Bubbles occurred under all lens types at depths as shallow as 6.5 feet following the least stressful exposure. Physiological corneal changes from bubble formation included corneal dimpling and localized corneal edema. Due to the tissue half-time of the eye, it is doubtful that the bubbles are a result of off-gassing of nitrogen from the eye.

INTRODUCTION

Recently, there has been a great deal of interest in wearing corneal contact lenses in underwater activities with self-contained underwater breathing apparatus (SCUBA). Several reports indicate that these lenses can be worn under water (1-8). There are, however, several types of contact lenses. It has been observed that hydrogel lenses worn in hyperbaric environments do not result in the complications (8) that have been noticed for many years with hard polymethylmethacrylate lenses (1-7). However, we know of no studies of the performance of rigid gas permeable lenses under hyperbaric environments. The purpose of this study, therefore, was to evaluate the available rigid gas permeable contact lens designs and materials during hyperbaric excursions. This was done using first generation cellulose acetate butyrate (CAB), second generation silicone-acrylate, and third generation silicone-acrylate rigid gas-permeable corneal contact lenses on trained subjects in a dry hyperbaric chamber.

METHOD

Subjects

Two men and two women who were qualified for the hyperbaric chamber volunteered as subjects.

Lenses

The subjects were randomly fit with three different rigid gas-permeable contact lenses: (1) Barnes-Hind, G.P.IIR, cellulose acetate butyrate (CAB) lenses, (2) Polymer Technology Boston IIR, siloxane-acrylate, and (3) Polymer Technology Boston IVR, siloxane-acrylate spherical contact lenses. Commercially available Boston solutions were used to clean and insert the lenses.

Procedure

The effects of the lenses on gas transfer and corneal response were evaluated both under pressure and at the surface using a photo slitlamp and Keratometer. The subjects' corneal-lens relationship was photographed with a slit lamp camera if unusual phenomena were observed. Snellen visual acuity was tested at the surface before and after the dives. Lens comfort was evaluated subjectively.

During the first hyperbaric exposures the subjects breathed compressed air in the double-lock in the NSMRL hyperbaric chamber at an exposure depth of 45.5m (150 feet of sea water), with a 30 minute bottom time. This initial depth and bottom time was modified in three subsequent dives to determine the reasons for the bubble formation. Due to the fact that nitrogen comes out of solution from the body tissues in the form of a gas rather slowly, we felt that reducing the dive time and depth would allow us to differentiate between diffused nitrogen released from tissues and nitrogen in solution in the tears. These subsequent dive profiles were 150 feet for 15 minutes, 75 feet for 15 minutes, and 37.5 feet for 15 minutes. The dives followed standard Navy Air Dive Tables for hyperbaric exposures (9); there were decompression stops at 20 feet for eight minutes and at 10 feet for 24 minutes for the first dive to 150 feet; there were stops at 20 feet for two minutes and at 10 feet for seven minutes for the second dive to 150 feet; there were no decompression stops for the third dive to 75 feet or for the fourth dive to 37.5 feet.

All four subjects performed the first dive to 150 ft for 30 min, alternating the lens type between the eyes each time. Two subjects performed each of the remaining dives three times, again alternating lens type each time. The same investigator (JFS) was in the chamber during all the dives. The dives took place in the mornings with an interval of 24 hours between dives; this is within the safety factor for repetitive dives as specified by the USN Diving Manual (9). Informed consent was obtained from the subjects after the protocol had been fully explained.

RESULTS

All the subjects reported that their lenses felt as comfortable or more comfortable after reaching the bottom and during the decompression phase of the dives than on the surface prior to diving. No subject reported any displacement of the lenses or visual changes throughout the dives. Examination by the investigator revealed that all lenses moved less while on the bottom. This conforms to our previous findings with the hydrogel lenses (8).

The chamber investigator first observed central bubbles under the lenses when the subjects reached the first decompression stop at twenty feet. The bubbles became more numerous during travel to the surface from the bottom. These central bubbles were very symmetrical, progressively grew and coalesced until they fractured into smaller bubbles by the time the surface had been reached.

More central bubbles were noted with the Boston II and Boston IV than with the GPII lenses at the twenty foot mark on the first and second dives. On the first dive, every eye had bubbles on reaching the surface, whereas on the second dive many of the bubbles disappeared upon surfacing. All bubbles were stationary; they did not move when the lens moved, as previously described by Betts (7). All bubbles left dimpling of the cornea after they disappeared.

Additionally, we noted that all eyes exhibited corneal edema at the surface in the first dive, and one subject continued to show signs of edema for four hours after removing the lenses.

Of the eight trials per lens over the three dives, bubble formation was greatest with the silicon-acrylate lenses. As the time and depth decreased, fewer bubbles formed. No lens displacement occurred in any of the bubble formation incidents (BFI) or in any of the trials. Keratometer corneal mire distortion was noted on two trials with the same subject with both silicon-acrylate and CAB lenses. Fifteen minutes later keratometric values were found to be normally clear and regular.

DISCUSSION

As in our previously reported hydrogel study (8), chamber humidity may be the reason why all our subjects reported the same or improved comfort after reaching the bottom and during the decompression phases of the dives as at the surface. The humidity inside the chamber at times approached 100%. This may have placed so much moisture on the lens and the eye that it was like instilling a few drops of eye solution. The increased humidity may also have caused increased lens hydration, which in turn results in a slightly looser lens.

Bubble formation incidence in this study appears to be the same phenomenon noted by Betts (7), Simon and Bradley (5), and Molinari and Socks (8). Visual side effects were not as severe as described by Simon and Bradley (5). While we noted BFI with these lenses, the corneal trauma from them seemed less than in the PMMA trials by Simon and Bradley. The GPII lenses appeared to reduce BFI significantly. Our limited number of exposures makes it difficult to relate BFI to materials alone. The relation of lens design to corneal toricity may be a factor in bubble formation. Our subjects had a very low amount of corneal astigmatism. Therefore, excess tear pooling is unlikely. All these variables are presently being evaluated.

No lenses were displaced under pressure. The same was true with the hydrogel lenses (8). For the sport diver as well as the military diver, this means that it is relatively safe to wear these devices in lieu of the cumbersome modified eye-wear in the mask. The effects of decompression physiology on the lens-cornea relationship does not appear to be a significant factor in corneal trauma. However, the corneal insult which did result from the bubble formation means that divers should wear rigid lenses with caution.

From these results, we conclude that nitrogen dissolved in the tears rather than tissue nitrogen is responsible for BFI. At the shallow depth of 37.5 ft, the eye tissues could not have saturated; only the tears could do so, and so we feel that only nitrogen from the tears could have produced the bubbles.

It is not obvious if either lens design or lens material is a factor. We do not completely understand the corneal distortion and mild edema post-dive. Further research is underway to determine the etiology.

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